Ref. No. : Ex/PG/MEC/PC/T/115B/2025

M.E. MECHANICAL ENGINEERING - FIRST YEAR - FIRST SEMESTER – 2025

COMPRESSIBLE FLUID DYNAMICS Time : 3 hours Full Marks : 100

Instructions : Answer any five (5) questions. Assume any missing data with justification.

1. (a) What do you mean by the speed of sound? Show that for a perfect gas, the speed of sound is $\sqrt{kRT}$, where the symbols carry usual meanings.

(b) Air flows adiabatically through a duct. At point 1 the velocity is 250 m/s with T_1=330 K and p_1=180kPa. Compute (a) T_{01}, (b) p_{01}, (c) ρ_{01} , (d) Ma, (e) V_{max}, and (f) V*. At point 2 further downstream V_2=290 m/s and p_2=135 kPa. (g) what is the stagnation pressure p_{02}? **(10+10)**

2. (a) Obtain the conditions for area-velocity relationships for the subsonic-diffuser, supersonic-nozzle, subsonic-nozzle, and supersonic-diffuser.

(b) Air flows isentropically through a variable-area duct. At section 1, A_1=20 cm^2 , p_1=300 kPa, $\rho_1=1.75$ kg/m^3 , and Ma_1=0.25. At section 2, the area is exactly the same, but the flow is much faster. Compute (a) V_2 , (b) Ma_2 , (c) T_2 , and (d) the mass flow. **(8+12)**

3. Air flows through a duct as shown in **Fig. 1**, where, $A_1=24$ cm^2, $A_2=18$ cm^2, and $A_3=32$ cm^2. A normal shock stands at section 2. Compute (a) the mass flow rate, (b) the Mach number, and (c) the stagnation pressure at section 3. It is given that $Ma_1=2.5$, $p_1=40$ kPa, and $T_1=30^0$ C. **(20)**

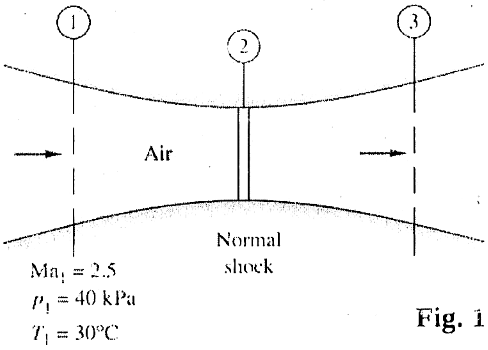

Fig. 1

4. A diamond, or double-wedge, airfoil of 2° half-angle and chord length C=2 m at $\alpha=8^0$ (angle of attack) in a stream with $Ma_\infty=2.5$ and $p_\infty=100$ kPa. Compute C_L and C_D by Prandtl-Meyer expansion theory. All the symbols carry usual meanings. **(20)**

5. (a) Supersonic air takes a 5° compression turn, as in **Fig. 2**. Compute the downstream pressure and Mach number and the wave angle

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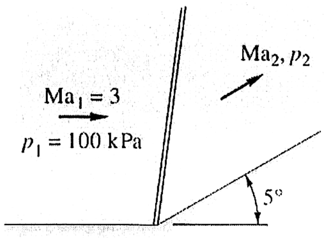
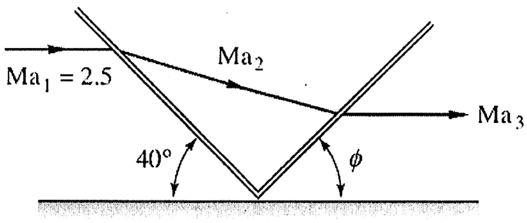


Fig. 2

(b) For an oblique shock wave, if δ is the deflection angle, β is the wave angle, and Ma is the upstream Mach number, show that

$$\tan\delta = \frac{2\cot\beta(Ma^2\sin^2\beta - 1)}{Ma^2(k+\cos 2\beta)+2}$$ **(10+10)**

6. When an oblique shock strikes a solid wall, it reflects as a shock of sufficient strength to cause the exit flow Ma_3 to be parallel to the wall, as in **Fig. 3**. For airflow with Ma_1=2.5 and p_1=100 kPa, compute Ma_3 , p_3 , and the angle ϕ .



(20)

Fig. 3

7. Draw the high-temperature shock layer on a blunt body moving at hypersonic speeds. Show that one may obtain a relationship for deflection angle for such a hypersonic flow as

$\delta = \frac{2}{\beta}\frac{Ma^2\beta^2}{Ma^2(k+1)}$, and hence show that for air with $k=1.4$, $\beta = 1.2\,\delta$. All the symbols carry usual meaning. **(20)**

(END OF THE QUESTION PAPER)